Some recent advances in

Agglomerating, Instantizing, and Spray Drying

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☐ AGGLOMERATING, instantizing, and spray drying are often linked together in the food industry, either as simultaneous processes or as consecutive manufacturing steps. Developments in one of these areas therefore often influence the others. This article reviews some recent technological advances in these three areas. Articles dealing more with the theoretical aspects of agglomeration—the most important means of instantizing—and spray drying can be found elsewhere (Masters, 1972; Masters and Stolze, 1973; Jensen, 1973).

Before discussing equipment and techniques, however, brief mention should be made of formulating products to enhance their instant properties. Some products require additives either because they are otherwise difficult to agglomerate or because agglomeration alone is not sufficient to achieve instant properties. Surfactants are often applied—whole milk powder is an important example—but are often combined with other additives or treatments. Adding sugar is a common means of enhancing the instant properties of many beverage powders. With proteinaceous powders such as sodium caseinate, addition of sugar is combined with application of surfactants (Palmer, 1973). A similar combination is used for egg white.

Examples of spray-dried products with specific formulations to make them readily dispersable in water are dry sweetener composition (Cella and Schmitt, 1973), sour cream powder (Noznick et al., 1974), and flavors for cocktail mixes (Anonymous, 1973).

REWET METHODS

Spray-dried food powders have a particle size that usually allows rewet agglomeration without pretreatment. Powders which contain components in the form of flakes or particles larger than about 80 μ, however, must be prepulverized. Similarly, if a product is preagglomerated to some extent, the agglomerates should be broken in order to provide a raw material consisting of individual particles only.

• **Steam Condensation.** Several methods of agglomeration apply the principle of condensing steam onto powder particles. The cooler the particles and their surroundings, the greater will be the degree of condensation achieved. Nestlé has used this principle by arranging for a supply of cooling gas to the agglomeration zone (Kleeman and Rothmayer, 1974). The moistening and agglomeration equipment shown in Figure 1 consists of a funnel for feeding the powder gravimetrically and one or two annular steam nozzles placed coaxially around the powder flow. When steam is injected, a cool gas, which may be an inert gas or just ambient air, will be sucked in through the annular openings between the powder flow path and the steam nozzles. This design seems ideal from the point of view of avoiding powder deposits. Applications of this equipment include orange drinks and cocoa/sugar mixtures.

• **Droplet Agglomeration.** In droplet agglomeration, wetting is accomplished by spraying the powder with a fine mist of water or other liquid or solution such as lecithin, dyestuffs, flavorings, etc.

The choice between steam condensation and droplet agglomeration is determined by the desired powder characteristics and the final product requirements. The plant shown in Figure 2 enables either method to be used by simply exchanging the moistening unit. Atomization of the wetting agent for droplet agglomeration is achieved by an atomizer wheel rotating at high speed. In the alternative arrangement for steam condensation shown by the dotted lines in Figure 2, moistening and agglomerating take place in a vertical tube where powder and steam are brought into con-

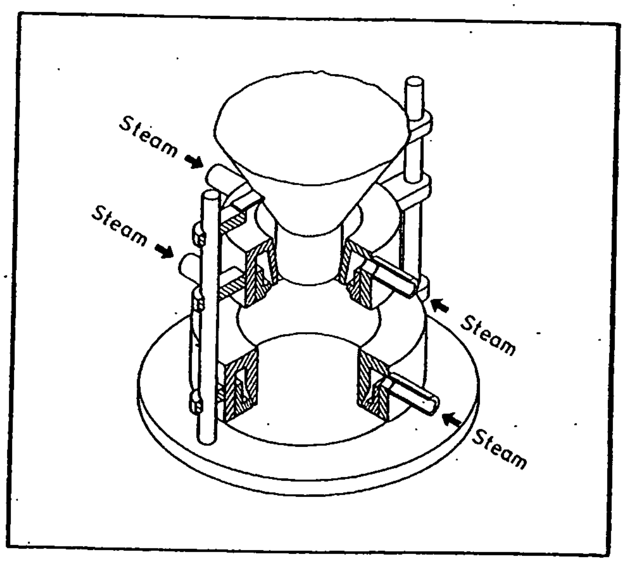

Fig. 1—**STEAM CONDENSATION** *rewet agglomeration unit has one or two steam nozzles placed coaxially around the powder funnel; when steam is injected, cool air or other gas is sucked through the opening between the funnel and the nozzles to condense the steam onto the powder*

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tact in a vortex manner. After-drying and cooling are carried out in a vibrating fluidized bed, such as Niro Atomizer's Vibro-Fluidizer™. Droplet agglomeration is more lenient on the product, whereas the agglomerating tube provides high impact forces, necessary for products that are not too readily wetted.

Requirements regarding the prevention of microbiological contamination are becoming more rigorous. The plant shown in Figure 2 meets these demands. All air supplied to the plant is filtered through ordinary air filters; regular control examinations of microbial quality have shown that high efficiency filters are unnecessary. In addition, the unit is extremely compact,—meaning that powder can be agglomerated at rates greater than 700 kg/hr in a plant having a 1-meter-diameter wetting chamber.

• **Granulating Disc.** The above methods may not be sufficient if larger agglomerates of products containing relatively large amounts of starch and sugars are required. Furthermore, edible dyestuffs readily become airborne, and "dusting" is a serious problem. These products may be satisfactorily agglomerated to non-dusty products in a granulating disc unit having short cylindrical sides and adjustable scrapers to prevent product buildup. The powder is cascaded onto the pan and moistened with water from a spray nozzle. The pan is inclined between 25° and 45° to the vertical and rotated at 10–25 rpm. These parameters, together with feed rates of powder and water, determine particle size and stability.

• **Rotating Cone.** Figure 3 represents a technique which is related to the granulating disc unit. In this case, the rotating part is in the form of a cone. Powder fed through a wide tube is wetted with water from a spray nozzle placed in the mouth of the tube. The wetted powder falls onto the cone and forms agglomerates while rolling down its surface. The cone is kept clean by stationary scrapers. This apparatus is being used for chocolate drinks, dairy products baby food, and instant breakfast mixes.

INSTANTIZING WHOLE MILK POWDER

Although agglomeration was the key process that created the success of instant skim milk powder in the 1950s and 1960s, agglomerating techniques known then were not able to solve the problem of instantizing fat-containing dairy products, such as whole milk powder. With the increasing demand for this product especially in the countries of the Far East, it has been necessary to direct greater research effort toward other factors that influence the reconstitution properties.

One modern process developed by Nestlé (Moury, 1965) is based on the recognition that it is especially that part of the free surface fat of the powder present in the solid state which has an impairing effect on wettability. Fractionation of butterfat is therefore carried out prior to drying of the milk concentrate. The high-melting fraction of the fat is recycled to the milk concentrate before it is spray-dried, and the low-melting fraction is applied as a coating on the dried powder.

This process can be simplified if the free fat content and the quantity of lecithin are controlled (Písecký and Westergaard, 1973). The powder used for after-treatment with lecithin should be of good quality (low solubility index, etc.) and should be well agglomerated, i.e., contain few individual particles and fines.

A plant for the manufacture of instant whole milk powdered by the simplified process is shown in Figures 4 and 5. The powder is dosed from the silo to

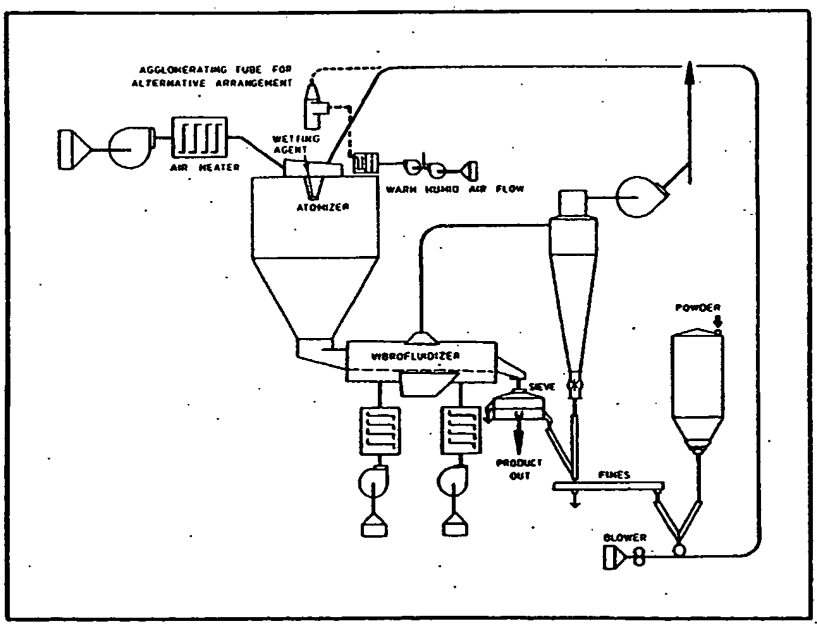


*Fig. 2—***INSTANTIZING PLANT** *allows either droplet agglomeration (in which an atomizer wheel rotating at high speed sprays the powder with a water mist) or steam condensation (in which steam and powder are vortex-mixed in a vertical tube, as shown by the dotted lines) to be used simply by changing the moistening unit*

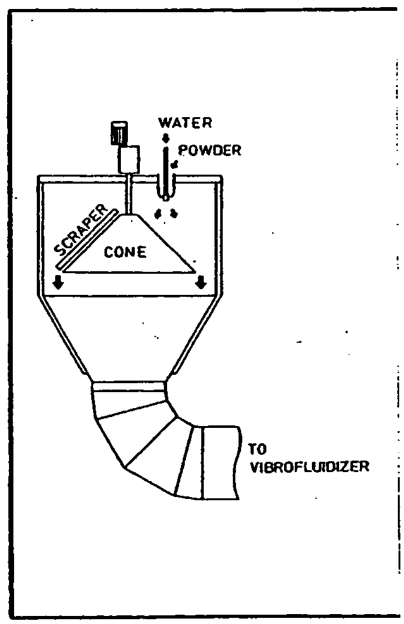


*Fig. 3—***ROTATING CONE UNIT** *aids droplet agglomeration; powder wetted by a water spray forms agglomerates as it rolls down the surface of the cone*

the first Vibro-Fluidizer, through which hot air is blown. This has a dual purpose: Coating hot powder has given the best results, and fines that are formed by mechanical attrition during transport of agglomerates can be removed—this is essential for the production of powder of good instant properties. Between the outlet of the first and the inlet of the second Vibro-Fluidizer, the agglomerates are treated with lecithin delivered through a two-fluid nozzle. The powder is then fluidized in the second Vibro-Fluidizer to equalize the lecithin coating of all the agglomerates. After the lecithination process, such a whole milk powder will be wetted and dispersed within a few seconds, even in ice-cold water.

There are three conditions that must be fulfilled in order to achieve a good result: First, the quantity of the surface layer of lecithin and free fat which are applied, plus the quantity of free fat which is already present, must be within the limits of 1–3% by weight of the powder. Second, the quantity of lecithin must be 15–25% by weight based on that part of the free surface fat which is liquid at ambient temperature. And third, this liquid fraction of the surface layer should have a thickness of at least 0.1 μ (Písecký and Westergaard, 1973).

Controlling all these measures is not as troublesome as it may sound. In a spray-drying process with straight-through instantizing (see below), the powder produced has fairly constant characteristics. The free fat content may vary from plant to plant, but once in operation, a particular plant will produce powder with constant free fat content. It is therefore possible to select a correct rate of lecithin supply so that the above three conditions are fulfilled. Only periodic adjustments to the process are thereafter required.

There is little information available in the literature on the effect of large-scale instantizing operations on the composition of the raw material. Although some essential amino acids in milk, for example, can be degraded easily by a combination o heat and moisture, Posati et al. (1974) showed tha commercial instantizing, whether by rewet or straight through methods, resulted in no marked loss of amin acids.

INSTANTIZING COFFEE

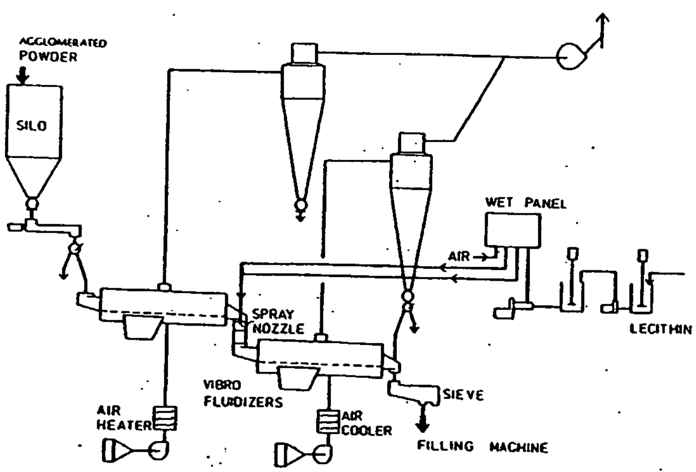
An objection to typical instant coffee is that it ha a pale tan color and a fine or even dusty appearanc which is quite unlike the ground roasted coffee wit which the consumer is familiar. There is no doubt however, that the demand for agglomerated instan coffee was strongly enhanced by the higher price o freeze-dried instant coffee introduced in 1965.

Agglomeration of instant coffee is very delicate because the powder is both hygroscopic and thermoplastic, and conventional agglomerating equipment is therefore useless. In the last few years, an intense research effort has been undertaken, and a number o processes have been suggested for the manufacture of this product.

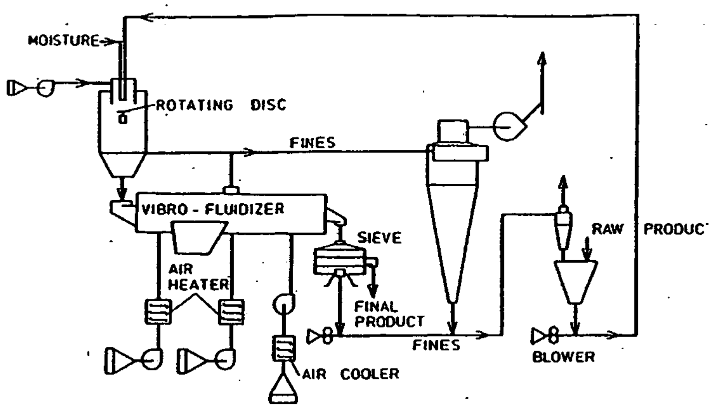
• General Foods Corp. has developed a method whereby powder is wetted in a falling curtain of powder (Purves et al., 1973; Sienkiewiez and Begley, 1973). The spray-dried coffee is pulverized in a hammer mill to break up the hollow spheres so that no air is entrapped; this eliminates foaming when the agglomerated powder is dissolved. The prepulverized powder falls from a vibrating feeder and forms a curtain which is impinged upon by steam jets. The agglomerates are redirected into a drying zone and carried to a cooling conveyor.

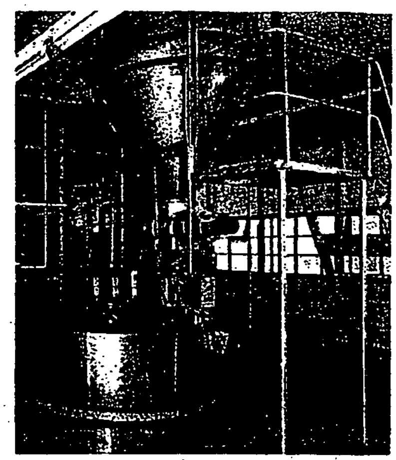
• The Nestlé rewetting unit shown in Figure 1 is also said to be able to agglomerate instant coffee.

• In Niro Atomizer's coffee-agglomerating unit shown in Figures 6 and 7, the essential feature is a fast rotating disc onto which the powder falls immediately after moistening (Hansen and Hansen, 1974).



Figs. 4 and 5—**PLANT FOR INSTANTIZING** *whole milk powder uses hot air to heat the agglomerated powder and remove fines, then coats agglomerates with lecithin*





Figs. 6 and 7—**COFFEE AGGLOMERATION PLANT** *uses a rotating disc onto which powder moistened by a spray and steam falls, agglomerates, and is flung off by centrifugal force; Fig. 7 shows the silo positioned over the wetting chamber containing the rotating disc, in Haco AG's plant in Switzerland*

Powder on its way from the feeder to the rotating disc is superficially moistened by liquid from a spray nozzle and steam. Immediately afterwards, the powder impinges upon the central area of the disc, which rotates at 1,000–5,000 rpm; this is high compared with conventional granulating discs. The actual speed is selected according to the product. Particles collide on the surface of the disc, and the agglomerates thus formed are flung off by centrifugal force. The agglomerates pass to the Vibro-Fluidizer, which acts as an after-dryer/cooler.

The principle of the rotating disc has proved very successful for agglomerating instant coffee, and several industrial plants are now in operation. The plant can also be used for products that are even more hygroscopic and thermoplastic, and which were previously considered impossible to agglomerate, e.g., coffee substitute, such as chicory.

STRAIGHT-THROUGH PROCESSES

In the methods described above, the agglomeration which is often sufficient to achieve instant properties is carried out *after* the powder has been manufactured. However, in the "straight-through" processes, agglomeration takes place *during* the spray drying, i.e., dur-

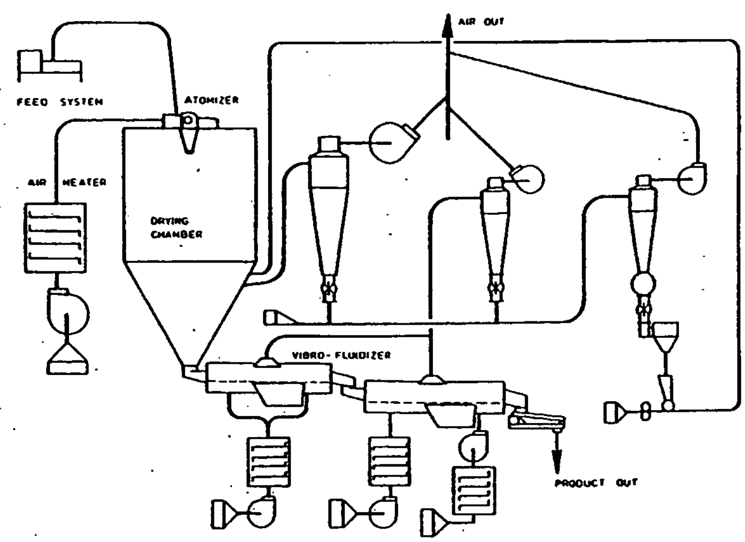


Fig. 8—**STRAIGHT-THROUGH PROCESS** *instantizes during and immediately after the individual particles are formed, rather than as a separate step after the particles are formed, as in the rewet method; basic factors are the low outlet temperature and the return of fines to the spray dryer*

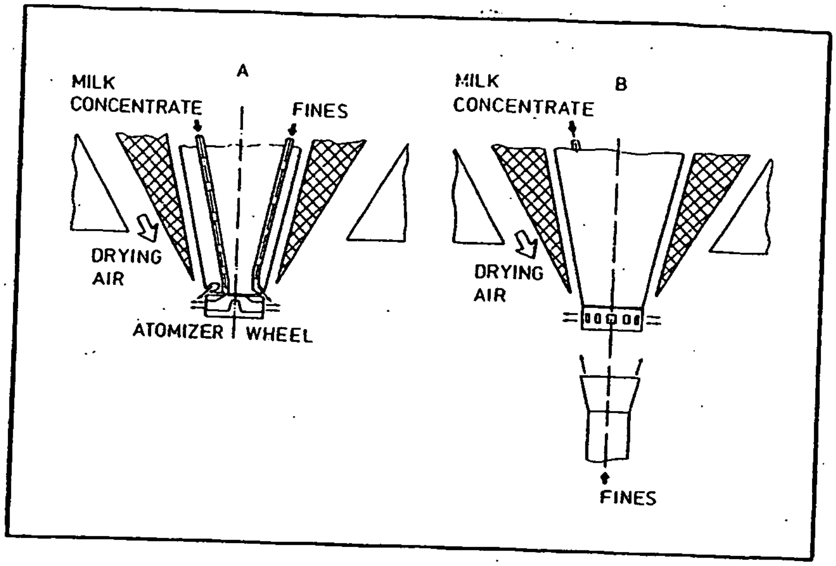


Fig. 9—**FINES MAY BE REINTRODUCED** *into the atomizing cloud in the process shown in Fig. 8 from an annular opening above the atomizer wheel (A) or through a central pipe from below (B)*

ing and immediately after the individual particles are formed. A typical straight-through instantizer system for milk products is shown in Figure 8.

The basic factors in this process are the low outlet drying temperature and the return of fines to the spray dryer. The low outlet temperature means that intermediate product leaves the spray dryer with a higher moisture content than the final product. Because of this, the agglomeration zone of the atomizing cloud is extended and the probability of clusters of particles being produced is greater than in conventional spray drying. The excess moisture is removed in the fluid bed dryers that follow the spray dryer.

There are two different ways of introducing the fines into the atomizing cloud. They may be projected from an annular opening above the atomizer wheel, as shown in Figure 9A, or they may be fed through a central pipe from below, as shown in Figure 9B. The latter arrangement has the advantage of reduced risk of adversely affecting the quality because the fine particles are protected from the hot drying air by the atomizing cloud.

The spray-dryer with straight-through instantizer is a very suitable system for the manufacture of instant skim milk powder. It is the preferred method for drying whole milk for subsequent instantizing with lecithin. It is also very suitable for the production of non-caking whey powder.

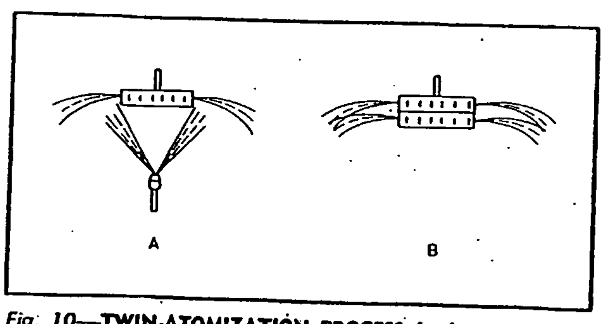


Fig. 10—**TWIN-ATOMIZATION PROCESS** *feeds two different raw materials (such as milk concentrate in one and a sugar solution in the other) to the spray dryer by (A) an atomizer wheel and nozzle or (B) a two-tier atomizer wheel*

There are also other spray dryer combinations which should be mentioned:

In the dryer described by Meade (1973), a conventional co-current nozzle spray dryer is used with a screen-mesh-type conveyor belt enclosing the bottom of the chamber. Partially dried product particles form a porous mat on the belt. Drying is completed on the porous bed in additional stages downstream from the spray chamber. The average bed thickness may be 2–4 in. Uniform after-drying appears to be a problem with products that become sticky, such as cottage cheese whey. The dried product leaves the system in mat form which is then broken or otherwise subdivided.

A technique which is of particular interest for products that contain added sugar or other carbohydrates is the twin-atomization process shown in Figure 10. It is similar to the straight-through process, but two different raw materials are fed to the spray dryer. One may be milk concentrate and the other a sugar solution. They are atomized separately into the same chamber by a wheel and nozzle (A) or a two-tier wheel (B). Two types of droplets will therefore be present in the atomizing cloud; this results in good agglomeration conditions and the formation of strong and stable agglomerates. An example of this application is the combining of acid whey and skim milk solids into products suitable for bakery use (Lundstedt, 1973).

NEW PROCESSES & TECHNIQUES

Although the demand for instant properties has been increasing in the past decade, important demands on the spray drying process have been made during the 1970s to achieve higher-bulk-density milk powder and—especially after the beginning of the energy

crisis—better heat economy. In certain markets, such as the Far East, where milk powder products are shipped over long distances and most of the products are reconstituted industrially rather than in the household, the demand for high bulk density seems to overshadow that for improved instant properties. Furthermore, high bulk density is desirable for powder that is to be instantized by the rewet method.

To meet these demands, Niro Atomizer has developed two new spray drying processes—the steam-swept-wheel process that yields a high-bulk-density product, and the two-stage drying process that satisfies the requirements for high bulk density as well as for better heat economy:

- **Steam-Swept-Wheel Process.** Verkey and Vos (1971) showed that it is possible to reduce the volume of occluded air in the spray-dried particles, and thereby increase the particle density, by flushing the interior of the atomizer wheel with steam. A rotary atomizer with a specially designed atomizer wheel (Fig. 11) has been developed for this steam-swept-wheel process (Písecký and Soerensen, 1974). It includes two separate feed systems, one for milk concentrate and one for steam. The method has proven successful on industrial-scale dryers.
- **Two-Stage Drying Process.** Detailed information on the two-stage drying process has been published by Písecký (1974). In the two-stage drying process, it is possible to obtain considerable shrinkage of the particles during spray drying, resulting in maximum particle density. At the same time, the inlet temperature of the drying air can be increased to 230°C, and in some cases even to 275°C, thereby improving the dryer heat economy without any detrimental effect upon the product solubility index.

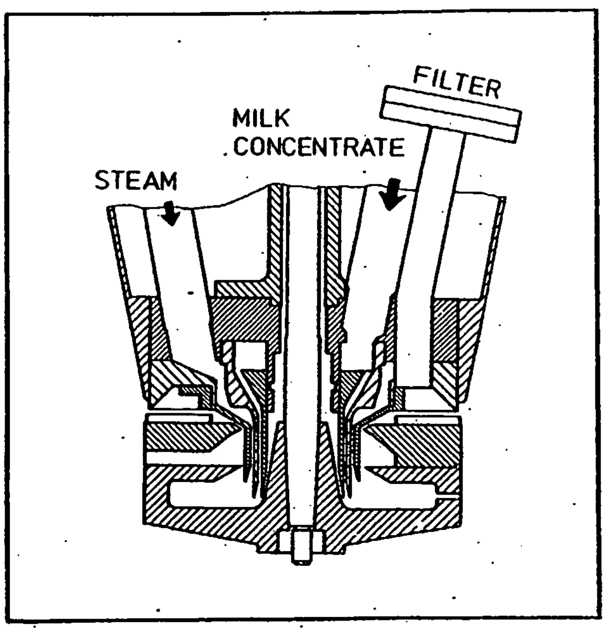


Fig. 11—**STEAM-SWEPT-WHEEL PROCESS** *flushes the interior of the atomizer wheel with steam to reduce the volume of occluded air in the spray-dried particles and thus increase the particle density*

Figure 12 shows a large skim milk particle dried from a concentrate with 42% total solids content by conventional spray drying at an inlet air temperature of 195°C. The droplet from which the particle is formed has been blown up and solidified to form a sphere. The circular section that is uncovered presumably has been a surface of contact with another particle. The particle contains many vacuoles. In contrast, Figure 13 shows a particle from the two-stage drying process. The total solids content of the concentrate was 50%, and the inlet air temperature was 250°C. Partially inflated compact particles are formed, thus explaining the high bulk density of the powder.

Recently, fluidized bed processing has been combined with atomization of the feed solution. In this method, the raw material is a solution or slurry which is atomized onto particles heated in a fluidized bed. The liquid may be sprayed either onto the surface of the bed or directly into the bed. Particle growth can occur either as agglomeration of several particles into larger particles, or as layering of solid onto individual particles—the so called "onion-skinning" effect.

Applications of the equipment cover a range of products, including inorganic and organic materials such as pharmaceutical products, dyestuff intermediates, and single-cell proteins. A continuous type of this equipment, Niro Atomizer's Spray Fluidizer™, is illustrated in Figure 14.

INDUSTRIAL EXPERIENCE ESSENTIAL

Applications of agglomerating, instantizing, and spray drying continue to widen. New food powders appear on the market, and new requirements are made for existing ones. Demands such as high mechanical stability and a specific bulk density for a given product often require strict control of the numerous process parameters described above and call for careful selection of processes and operating conditions.

Although theoretical principles provide a useful background and laboratory tests help in acquiring practical information, industrial-scale experience and know-how are really the only safe basis for securing desired results in large-scale operations.

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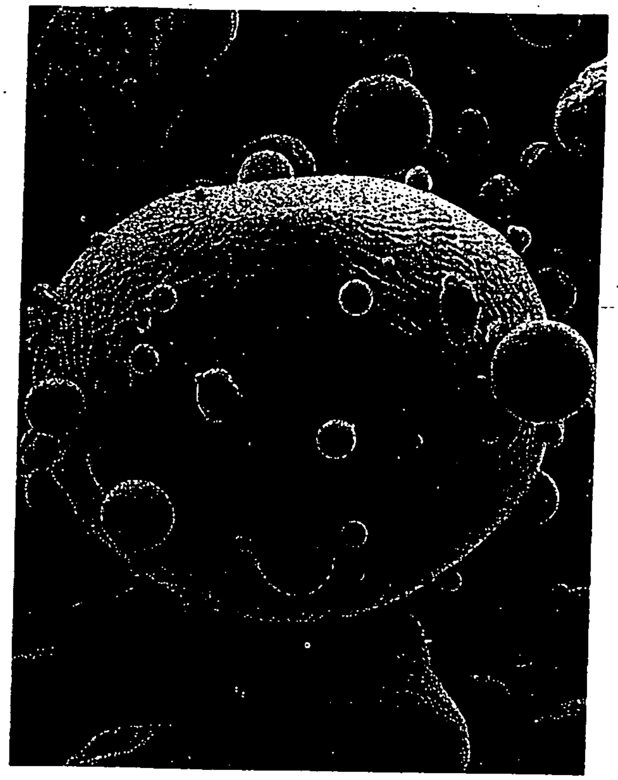

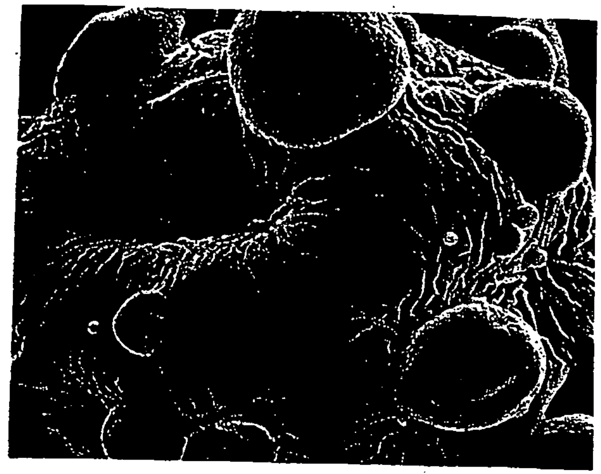

Figs. 12 and 13—**PHOTOMICROGRAPHS OF SKIM MILI PARTICLES** *conventionally spray dried (Fig. 12 at left) an spray-dried in a two-stage drying process to give a highe bulk density (Fig. 13 above)*

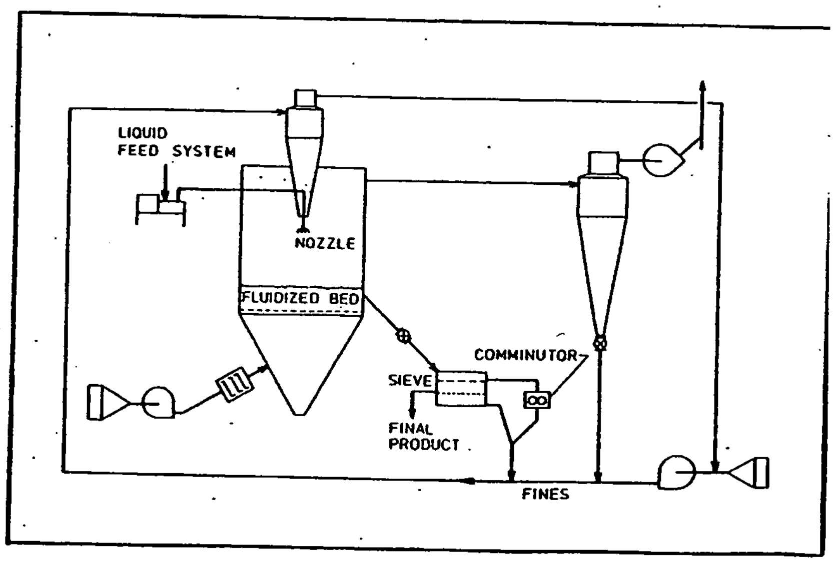

Fig. 14—**SPRAY DRYER-FLUIDIZED BED SYSTEM** *atomizes a solution or slurry onto particles heated in a fluidized bed; particle growth can occur either as agglomeration of several particles into larger ones or as layering of solid onto individual particles*

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